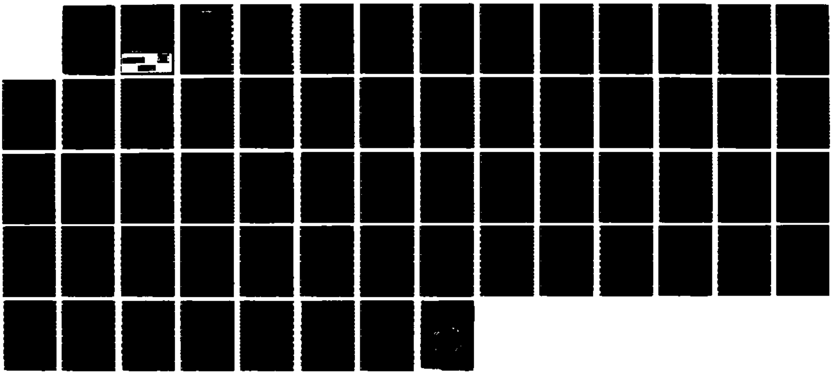
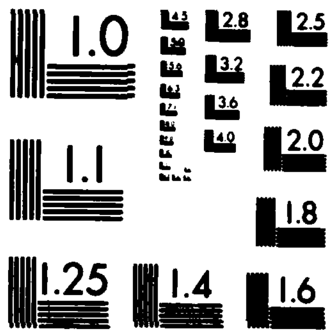
AD-A174 093 EVALUATION OF ALTERNATIVES FOR ARMY PRECISION LANDING SYSTEM GROUND GUIDANCE(U) ARINC RESEARCH CORP ANNAPOLIS MD C BOYD ET AL JUL 86 2959-01-2-4106 1/1

UNCLASSIFIED DAEA18-84-C-0127 F/G 17/7 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ARINC Research Publication 2959-01-2-4106

2

FINAL REPORT

EVALUATION OF ALTERNATIVES FOR ARMY PRECISION LANDING SYSTEM: GROUND GUIDANCE

AD-A174 093

July 1986

Prepared for
U.S. ARMY INFORMATION SYSTEMS COMMAND
U.S. ARMY AIR TRAFFIC CONTROL ACTIVITY
ATTN: ASQ-DD
FORT HUACHUCA, ARIZONA 85613-5380
under Contract DAEA18-84-C-0127
Tasks 1-4, CDRL Item A008
September 1985 - July 1986

ARINC RESEARCH CORPORATION

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARINC Research Corp. No. 2959-01-2-4106	2. GOVT ACCESSION NO. AD-A174473	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* Evaluation of Alternatives for Army Precision Landing System: Ground Guidance		5. TYPE OF REPORT & PERIOD COVERED Research/Study Report 1 Oct 85 - 31 Jul 86
		6. PERFORMING ORG. REPORT NUMBER No. 2959-01-2-4106
7. AUTHOR(s) C. Boyd, J Gruhler, R. Lewsen — Arinc Research Corporation		8. CONTRACT OR GRANT NUMBER(s) DAEA 18-84-C-0127
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Air Traffic Control Activity, ATTN: ASQ-DD, Fort Huachuca, AZ 85613-5380		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 395114A (Program Element) USAATCA
11. CONTROLLING OFFICE NAME AND ADDRESS Development Directorate, ASQ-DD, Fort Huachuca, AZ 85613-5380		12. REPORT DATE July 1986
		13. NUMBER OF PAGES 58
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* Same as No. 9 above.		15. SECURITY CLASS. *(of this report)* Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT *(of this Report)*

Report approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

Same as above.

18. SUPPLEMENTARY NOTES

DTIC No. DA 304796

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Precision approach radar, global positioning system, forward area arming and refueling point, forward looking infrared, Doppler Navigation System. Instrument meteorological conditions, night navigation, pulse light approach slope indicator.

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report deals with current and planned aircraft guidance systems as they apply to Army tactical precision landings in the combat environment. Self-contained avionics systems and less sophisticated systems have been evaluated. Ground guidance is defined as a means to safely, efficiently, and rapidly aid in the movement of aircraft from their transition point of landing to a final destination. The study addressed the following four tasks: 1)

- Review Army Requirements (Ground Guidance) by research of current

documentation and by extensive interviews. 2)

Identify alternative systems through specifications and discussions with government and industrial personnel. 3)

Evaluate systems by conducting aviator and engineer evaluations. and 4)

Identify and document best approach for Army use in the tactical environment.

FINAL REPORT

EVALUATION OF ALTERNATIVES FOR ARMY PRECISION LANDING SYSTEM: GROUND GUIDANCE

July 1986

Prepared for

U.S. Army Information Systems Command
U.S. Army Air Traffic Control Activity
Attn: ASQ-DD
Fort Huachuca, Arizona 85613-5380

under Contract DAEA18-84-C-0127
Tasks 1-4, CDRL Item A008
September 1985 - July 1986

Accession For		
NTIS GRA&I	X	
DTIC TAB	☐	
Unannounced	☐	
Justification		
By		
Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A-1		

by

C. Boyd
J. Gruhler
R. Lewsen

ARINC Research Corporation
a Subsidiary of Arinc Incorporated
2551 Riva Road
Annapolis, Maryland 21401

Publication 2959-01-2-4106

ABSTRACT

This report presents ARINC Research Corporation's comprehensive survey of Army ground guidance requirements, identifies alternatives, and evaluates the systems versus the requirements. This evaluation describes the requirements and systems of choice for ground guidance tactical terrain flight levels. The report was accomplished within the context of the previous effort, Evaluation of Alternatives for an Army Precision Landing System (ARINC Research Publication 2959-01-1-3759, September 1985), and current air traffic management functions.

GLOSSARY OF
ABBREVIATIONS AND ACRONYMS

ACCS	Army Command and Control System
ADAS	Army Digital Avionics System
ADEA	U.S. Army Development and Employment Agency
ADF	Automatic Direction Finder
AGL	Above Ground Level
AHIP	Advanced Helicopter Improvement Program
APLS	Army Precision Landing System
ATC	Air Traffic Control
ATM	Air Traffic Management
AVIM	Aviation Intermediate Maintenance
AVRADA	Avionics Research and Development Activity
BDHI	Bearing Distance Heading Indicator
CDS	Control Display System
CDU	Computer Display Unit
CIU	Control Indicator Unit
CRT	Cathode Ray Tube
C^3	Command, Control, and Communications
CW	Continuous Wave
DA	Department of the Army
DH	Decision Height
DMA	Defense Mapping Agency
DMG	Digital Map Generator
DNS	Doppler Navigation System
DRVS	Doppler Radar Velocity Sensor
ECM	Electronic Countermeasures
EPUU	Enhanced PLRS User Unit
FARP	Forward Area Arming and Refueling Point
FLIR	Forward-Looking Infrared
FLOT	Front Line of Troops
F^3	Form, Fit, Function
GPS	Global Positioning System

HOGE	Hover-Out-of-Ground Effects
HOL	Higher-Order Language
HSI	Horizontal Situation Indicator
ICNIA	Integrated Communications, Navigation, and Identification Avionics
ICS	Interim Contractor Support
IEW	Intelligence and Electronic Warfare
IINS	Integrated Inertial Navigation System
ILDNS	Improved Lightweight Doppler Navigation System
IMC	Instrument Meteorological Condition
IMPS	Integrated Mission Planning Station
INS	Inertial Navigation System
IR	Infrared
JTIDS	Joint Tactical Information Distribution System
km	Kilometer
LDNS	Lightweight Doppler Navigation System
LOS	Line of Sight
LPI	Low Probability of Intercept
LRU	Line Replaceable Unit
LZ	Landing Zone
MDA	Minimum Descent Altitude
MEDEVAC	Medical Evacuation
MHE	Material Handling Equipment
MOPP	Mission-Oriented Protective Posture
MOS	Military Occupational Specialty
MS	Master Station
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
M/V	Manpack/Vehicular
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, Chemical
NCS	Net Control Station
NDB	Nondirectional Beacon
NET	New Equipment Training
NNAPS	Night Navigation and Pilotage System
NOE	Nap of the Earth
NPU	Navigation Processing Unit
NVG	Night Vision Goggles
O&O	Operational and Organizational
OFP	Operational Flight Program

PAPI	Precision Approach Path Indicator
PCDP	Pilot Control and Display Panel
PIP	Product Improvement Program
PJH	PLRS/JTIDS Hybrid
PLASI	Pulse Light Approach Slope Indicator
PLRS	Position Location Reporting System
PVT	Position, Velocity, and Time
RAC	Radiometric Area Correlator
ROC	Required Operational Capability
RPU	Receiver/Processor Unit
RTA	Receiver/Transmitter Antenna
SCNS	Self-Contained Navigation System
SDC	Signal Data Converter
SDU	Signal Converter Unit
SEMA	Special Electronics Mission Aircraft
STANAG	Standardization Agreement
TACAN	Tactical Air Navigation
TAOR	Tactical Area of Responsibility
TAS	True Airspeed
UE	User Equipment
UHF	Ultra-High Frequency
USAATCA	U.S. Army Air Traffic Control Activity
UTM	Universal Transverse Mercator
UU	User Unit
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Regulation
VMC	Visual Meteorological Condition
VOR	VHF Omnirange Receiver

CONTENTS

Page

ABSTRACT v

GLOSSARY OF ABBREVIATIONS AND ACRONYMS vii

CHAPTER ONE: INTRODUCTION 1-1

1.1 Objective 1-1
1.2 Background of Ground Guidance Requirements 1-1
1.3 Methodology 1-3
1.4 Report Organization 1-4

CHAPTER TWO: REQUIREMENT FOR GROUND GUIDANCE AND ALTERNATIVE SYSTEMS. 2-1

2.1 Requirement for Ground Guidance 2-1
2.2 Alternative Systems 2-2

2.2.1 NATO Standardization Agreement (STANAG) 2351 . . 2-2
2.2.2 Nondirectional Beacon (NDB), AN/TRN-30 (V1)(V2) 2-3
2.2.3 Lightweight Doppler Navigation System (LDNS), AN/ASN-128 2-3
2.2.4 Improved Lightweight Doppler Navigation System (ILDNS), AN/ASN-137. 2-4
2.2.5 Integrated Inertial Navigation System (IINS), AN/ASN-132 2-4
2.2.6 Position Location and Reporting System (PLRS), AN/TSQ-129 2-4
2.2.7 PLRS/JTIDS Hybrid (PJH). 2-5
2.2.8 NAVSTAR Global Positioning System (GPS). 2-5
2.2.9 GPS/Doppler and GPS/Inertial Hybrid Systems. . . 2-6
2.2.10 Night Navigation and Pilotage System (NNAPS) . . 2-6
2.2.11 Other Systems Considered But Not Evaluated . . . 2-8

2.3 Factors Considered. 2-8
2.4 Summary 2-10

CONTENTS (continued)

		Page
CHAPTER THREE:	FACTOR AND SYSTEM EVALUATIONS	3-1
3.1	Factors Survey	3-1
3.2	Evaluation Methodology	3-4
3.3	Alternatives Survey	3-7
3.4	Final Survey Merge and Evaluation	3-10
3.5	Sensitivity Analysis	3-10
3.6	Summary	3-10
CHAPTER FOUR:	CONCLUSIONS AND RECOMMENDATIONS	4-1
4.1	Conclusions	4-1
4.2	Recommendations	4-2
APPENDIX A:	AIRLAND BATTLE AND TERRAIN FLIGHT	A-1
APPENDIX B:	ALTERNATIVE SYSTEM DESCRIPTIONS	B-1
APPENDIX C:	GROUND GUIDANCE CHARACTERISTICS	C-1
APPENDIX D:	ORGANIZATIONS VISITED AND PERSONNEL INTERVIEWED	D-1

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Microwave Landing System	1-2
1-2	Dispersion of Aircraft	1-3
3-1	Survey Methodology	3-7
3-2	Sensitivity Analysis	3-12

LIST OF TABLES

Table		Page
2-1	Alternative Ground Guidance Systems	2-3
2-2	Other Systems Examined	2-9
2-3	Factors Considered for Ground Guidance Evaluation	2-9
3-1	Experience Profile of Personnel Surveyed (Ft. Lewis)	3-2

CONTENTS (continued)

LIST OF TABLES (continued)

Table		Page
3-2	Experience Profile of Personnel Surveyed (Ft. Bragg). . .	3-3
3-3	Experience Profile of Personnel Surveyed (Ft. Campbell) .	3-4
3-4	Army VFR Weather Minimums (Uncontrolled Airspace)	3-5
3-5	Requirements Ratings.	3-6
3-6	Aviator Merged Ratings.	3-8
3-7	Alternatives Survey	3-9
3-8	Evaluation Matrix	3-11

CHAPTER ONE

INTRODUCTION

1.1 OBJECTIVE

The objective of this evaluation is to identify the best approach to satisfy the U.S. Army's tactical terrain, including Nap-of-the-Earth (NOE) ground guidance requirements for helicopters. The specific guidance followed included the approach from the previous report, Evaluation of Alternatives for an Army Precision Landing System (ARINC Research Publication 2959-01-1-3759, September 1985), air-traffic management (ATM) functions, and current tactical doctrine.

1.2 BACKGROUND OF GROUND GUIDANCE REQUIREMENTS

Under Contract DAEA18-84-C-0127, ARINC Research conducted a study to document U.S. Army requirements for a precision landing system. Special emphasis was placed on forward-area operations with the maneuver brigades. A strong categorical objection to precision landing systems was raised concerning the possibility of exploitation of any type of ground-based emitter. This concern led to the following developments:

- Army requirements documentation now specifies that there will be no precision landing systems in the brigade area, as discussed with personnel from the office of the Deputy Chief of Staff for Combat Development, U.S. Army Aviation Center, Ft. Rucker, Alabama, and the U.S. Army's Draft Required Operational Capability (ROC) for the new Microwave Landing System.

- The previous study derived the requirement for a precision landing point in the forward area remote from such destinations as a Forward Area Arming and Refueling Point (FARP) and medical clearing station by one to five kilometers. These distances are not meant to be concrete figures but are estimates based on the terrain, threat, and real estate availability. The one- to five-kilometer distance allows isolation of the FARP from the landing guidance signal to prevent attack.

Figure 1-1 illustrates three segments of a typical precision instrument approach, as follows:

- Transition from en route to terminal guidance
- Guidance from a transition fix to a minimum descent altitude (MDA) or decision height (DH), or hover-out-of-ground-effects (HOGE) point as used in the previous study
- Guidance from MDA/DH to final landing point

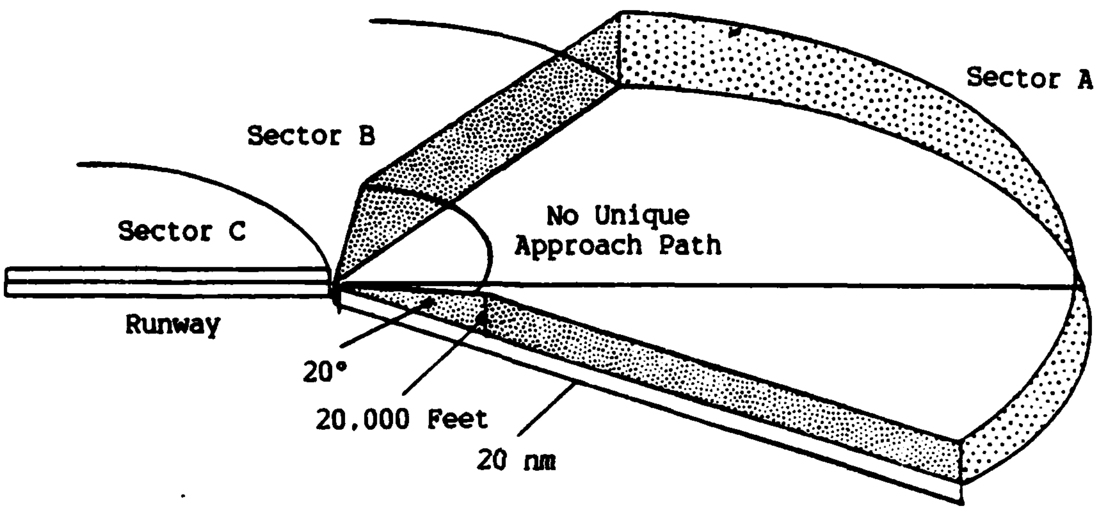


FIGURE 1-1

MICROWAVE LANDING SYSTEM

The previous study dealt with Sector B. Sector A, the transition from flight-following to approach control, will be addressed under the Combat Support Air Traffic Management task by Ft. Rucker personnel. Sector C is not normally a factor; however, for forward-area helicopter operations in marginal visual meteorological conditions (VMC) or Category I or II instrument meteorological conditions (IMC), Sector C becomes a one- to five-kilometer guidance problem (see Figure 1-2) that extends from the DH/MDA point to a remote FARP or other destination. This navigation may consist of a series of maneuvers that do not necessarily conform to typical precision-approach guidance scenarios.

All current and planned aircraft guidance systems applicable to Sector C have been considered in this study. Self-contained avionics systems such as GPS, inertial doppler, and combinations of the above have been evaluated, together with less sophisticated systems such as nondirectional beacons and map-reading/dead-reckoning. Command and control systems

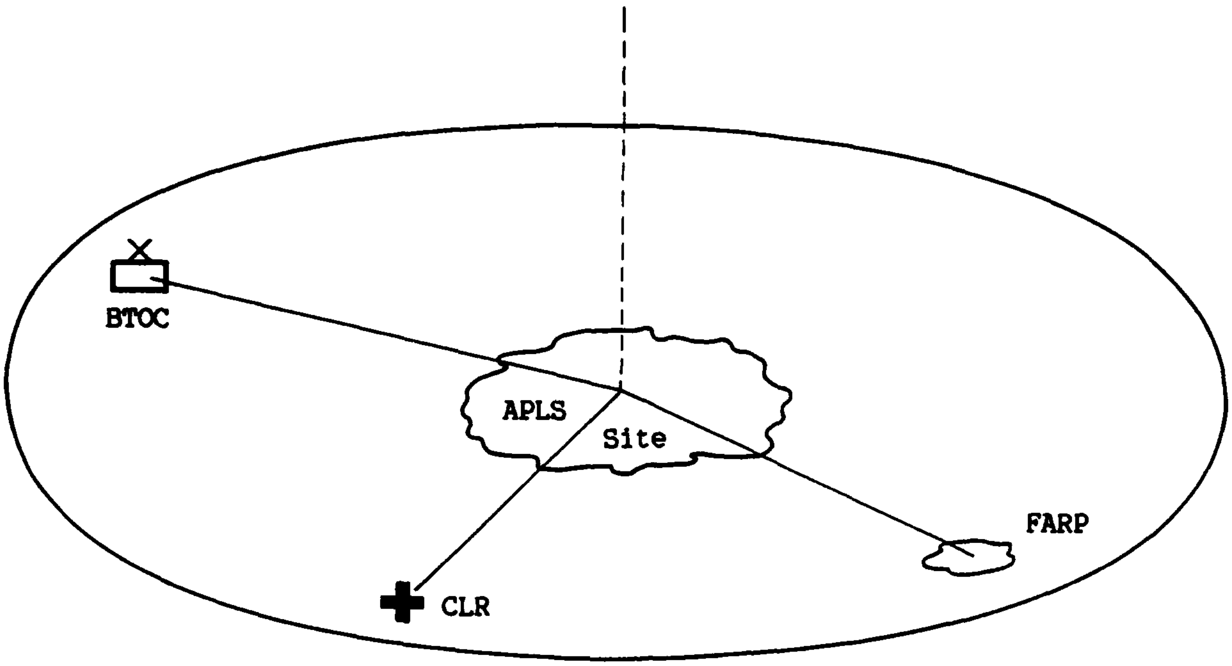


FIGURE 1-2

DISPERSION OF AIRCRAFT

such as Position Location Reporting System (PLRS) or PLRS/Joint Tactical Information Distributed Systems (JTIDS) Hybrid (PJH) were also considered as potential terminal navigation aids.

The definition of ground guidance as used in the context of this study is: A means to safely, efficiently, and rapidly aid in the movement of helicopters from their transition point of "landing" to a final destination.

1.3 METHODOLOGY

In conducting our evaluation, we addressed the following four tasks as defined in the contract Statement of Work:

- Review Army Requirements. Reviewed numerous documents and conducted extensive field interviews.

- Identify Alternative Systems. Reviewed specifications and held discussions with many Government and industrial laboratory personnel.

- Evaluate Alternative Systems. Conducted aviator and engineer evaluations and merged the results.

- Identified and Documented Best Approach.

1.4 REPORT ORGANIZATION

Chapter Two provides an overview and determination of Army requirements and possible alternative systems for helicopter ground guidance. Chapter Three addresses the evaluation, which includes a requirements survey by Army aviators, an alternative system survey by avionics engineers, a merging and evaluation of the two surveys, and a sensitivity analysis. Chapter Four presents conclusions and recommendations.

Appendix A presents an overview of Army terrain flight levels and flight navigation procedures at very low altitudes. Appendix B describes the evaluated alternative systems. Appendix C provides definitions of the ground guidance general characteristics. Appendix D lists the military and civilian organizations visited and personnel interviewed.

CHAPTER TWO

REQUIREMENT FOR GROUND GUIDANCE AND ALTERNATIVE SYSTEMS

This chapter presents a discussion of the requirement for a ground guidance system, provides alternative systems to be evaluated against the requirement, and lists factors to be considered in the evaluation.

2.1 REQUIREMENT FOR GROUND GUIDANCE

Army tactical helicopters will be employed in the entire Corps/ Division Tactical Area of Responsibility (TAOR). When Army helicopters are deployed with maneuver brigades, there is an absolute requirement for tactical terrain flight, an extremely demanding task for the aircrew. On-board navigation equipment that will minimize the aircrew workload is required, since pilots must navigate in unfamiliar (often mountainous) terrain, around the clock, and in adverse weather conditions. Terrain flight is the employment of a helicopter in such a manner as to utilize terrain, natural, and manmade objects to enhance survival by degrading the enemy's ability to optically and electronically detect, locate, and engage the helicopter. Terrain flight involves the aircrew's constant awareness of the position and location of enemy air defense systems in relation to the planned flight route. Terrain flying includes three methods of flying very close to the earth's surface: low level, contour, and NOE flight (see Appendix A for further explanation of terrain flight).

Maintaining visual contact with the ground and using the topographic map, together with the associated coordination required between the two helicopter pilots are classic examples of elementary "pilotage," or a basic "ground guidance system." Numerous sensor systems exist by which the aircrew can maneuver and navigate a helicopter at NOE altitudes. However, it is not currently possible or practical to install some of the large, heavy, and expensive systems in present or planned small tactical helicopters. The source of aircrew perceptual information (i.e., a pilotage system) varies from the unaided eye for clear daylight conditions to night vision goggles (NVGs) and forward-looking infrared (FLIR) systems for moon and starlight conditions to high-resolution radar imaging systems for an IMC environment.

With the exception of the new AH-64A Apache attack helicopter, the Army aviator's primary method for ground guidance NOE navigation is a hand-held topographic map, NVGs if required, and a Doppler Navigation System (DNS), if installed. Both pilots wear NVGs when flying at night or when daylight visibility is severely reduced by adverse weather. The aircraft's electronic heading reference indicator (compass) is used for azimuth information required while using the map. If available, the AN/ASN-128 or AN/ASN-137 DNS provide present-position, ground speed, and steering information and can be preset for the objective area position and various waypoints. The DNS is also completely self-contained, requiring no externally referenced navigation systems or navigation aids. Although the DNS can be programmed for azimuth and distance information to waypoints that assist the aircrew to track a minimum-risk route, it loses accuracy over distance flown. Present-position updating is required to correct this characteristic. Consequently, the aircrew will be using the DNS for back-up navigation when flying NOE. A hybrid navigation system will be used with the DNS in the near future for constant position updating.

Realistically stated, almost the entire Army helicopter aviator community is using a standard 1:50,000 topographic map for primary navigation. This map is used to assemble and collate the myriad of information required to plot friendly and enemy force distribution, battle positions, aerial observation points, landing zones (LZs), primary and alternative routes of flight, FARPs, barrier features, location of wires and other passive hazards to flight, and friendly and enemy air defense systems.

The following section describes alternative current and future navigation and command and control systems that are planned for installation in some present Army helicopters and the future single-piloted LHX.

2.2 ALTERNATIVE SYSTEMS

The alternative systems and a manual procedure that will assist aircrews with ground guidance evaluated in this report include existing and planned navigation and command and control systems. The alternatives were limited to those which are capable of terrain flight navigation in the immediate vicinity of a remote area landing zone that may include a tactical precision approach system or for navigation to any location in the Division/Corps TAOR. Table 2-1 lists the systems considered. The following subsections provide descriptions to acquaint the reader with the salient features of each. Appendix B presents detailed descriptions.

2.2.1 NATO Standardization Agreement (STANAG) 2351

The STANAG is a manual procedure whereby individuals on the ground can guide the helicopter pilots with hand and arm or light signals to a marshalling area. This procedure would assist the aircrew to air-taxi from the LZ in adverse weather to an unfamiliar marshalling area a short distance from the LZ. This procedure is not a candidate for a ground guidance system; but these are the procedures that must be followed, especially in a NATO theater of operations. "Pilotage" as used today and

TABLE 2-1

ALTERNATIVE GROUND GUIDANCE SYSTEMS

North Atlantic Treaty Organization (NATO) Standardized Agreement (STANAG) 2351, Procedures for Marshalling Helicopters in Multinational Land Operations
Nondirectional Radio Beacon (NDB), AN/TRN-30(V)1(V)2
Lightweight Doppler Navigation System (LDNS), AN/ASN-128
Improved Lightweight Doppler Navigation System (ILDNS), AN/ASN-137
Integrated Inertial Navigation System (IINS), AN/ASN-132
Position Location Reporting System (PLRS), AN/TSQ-129
PLRS/Joint Tactical Information Distribution System (JTIDS) Hybrid (PJH)
NAVSTAR Global Positioning System (GPS)
GPS/Doppler and GPS/Inertial Hybrid Systems
Night Navigation and Pilotage System (NNAPS)

which, in final form, uses these procedures is the manual procedure evaluated.

2.2.2 Nondirectional Beacon (NDB), AN/TRN-30 (V1)(V2)

This nondirectional, highly portable radio beacon can be employed in a tactical/semi-fixed or pathfinder configuration. It has a 46-kilometer range with a 30-foot antenna. Although an NDB has no range information capability, it would assist the aircrew with terrain flight navigation by providing a constant relative bearing to the beacon.

2.2.3 Lightweight Doppler Navigation System (LDNS), AN/ASN-128

The LDNS, in conjunction with the aircraft's heading and vertical references, provides accurate aircraft velocity, position, steering, and distance-to-go information from NOE level to well above 10,000 feet. It is a completely self-contained system, does not require any ground-based aids, and only weighs 29.4 pounds. The system provides worldwide navigation with position readouts available in both universal transverse mercator (UTM) and latitude/longitude displayed via a cockpit-mounted computer display unit (CDU). Up to 10 destinations may be entered in either format. Present-position data entry format is also optional and independent of destination format. Waypoints selected from the topographic map to fly a

minimum-risk route to a destination can be preset, thereby easing considerably the pilot and copilot workload with NOE navigation. Changes in route or destination can be made during flight. During periods of extremely reduced visibility the aircrew could use the system almost exclusively as a dead-reckoning navigator for short distances, if the flight began with a positive preset present position. Use of the topographic map would not be eliminated but might be minimized.

2.2.4 Improved Lightweight Doppler Navigation System (ILDNS), AN/ASN-137

The AN/ASN-137 is a product improvement program (PIP) version of the AN/ASN-128. The AN/ASN-137 employs the MIL-STD-1553 data bus and electronically centralizes the aircraft instrument headings on a single video screen with improved accuracy. Aircrew assistance with terrain flight is essentially the same for the AN/ASN-137 as for the AN/ASN-128.

2.2.5 Integrated Inertial Navigation System (IINS), AN/ASN-132

The IINS provides self-contained, passive navigation capability. Waypoints and destination features via a CDU are basically the same as for the doppler systems. Currently, only special electronic mission aircraft (SEMA) applications have been identified for the IINS, which is currently PIP for the EH-60 Quick Fix, replacing the AN/ASN-86 INS. System accuracy is partially a function of the quality and frequency of present-position updates. These updates can be entered manually or automatically, if a TACAN station is available. Although most helicopter SEMA missions are flown in the division area at flight levels far exceeding terrain flight altitudes, the AN/ASN-132 is an obvious excellent NOE navigator. The accuracy of the system is classified, but it is more accurate than a doppler navigator. The four major components (less the AN/ARN-118 TACAN) weigh 144 pounds and require an initial alignment time of nine minutes. The ASN-132 provides the aircraft location with extremely high tolerances, exceeding the AN/ASN-128 or -137. In addition, it has no radar signature.

2.2.6 Position Location and Reporting System (PLRS), AN/TSQ-129

PLRS is a ground commander's command and control UHF radio network consisting of up to 400 individual user units (UUs). The UUs are manpack-deployed or installed in vehicles or aircraft. Each UU automatically transmits a self-identifying signal burst on a precise time-ordered schedule, measures time of arrival of the other UU transmissions, and automatically relays these measurements under a master station (MS) control. The MS does the position location and tracking as well as providing report messages to the users and C^3 function. The MS is also a fully automatic network manager. By substituting an airborne power adapter for the manpack battery and a pilot control and display panel (PCDP), the basic UU adapts to the aircraft.

Terrain flight navigation will be greatly enhanced if a helicopter is PLRS-equipped. The PCDP, very similar to the inertial and doppler CDU, will display constantly the changing range and bearing to predesignated locations such as LZs or through minimum-risk waypoints. The aircrew can

interrogate and navigate to a UU at a fixed site or to a unit or vehicle on the move, including in-flight rendezvous with other PLRS-equipped helicopters. When airborne, the command and control personnel, via the MS, can send zone proximity alerts or guidance away from or out of danger areas. They could also cancel the original mission and forward all navigation and ancillary information required to perform the new mission. The PLRS is not a primary aircraft navigation system, and it will not eliminate the pilot/copilot coordination required for ground guidance using the topographic map, but it will greatly decrease their navigation workload. The PLRS will supplement and back up the aircraft primary self-contained navigation system.

2.2.7 PLRS/JTIDS Hybrid (PJH)

Building on the developments and investments already made in PLRS and JTIDS, the new PJH is a hybrid of both. The Army has decided on the acquisition of PJH instead of PLRS. PJH forms an enhanced, highly jam-resistant command and control system, encompassing both air and ground forces. All PLRS capabilities are retained but when compared with PLRS, PJH will significantly increase the quantity of data that can be transmitted between battlefield components. It will also permit enhanced interface with USAF and other service JTIDS-equipped aircraft supporting Army ground units and will establish direct user-to-user communications links. PJH employs the enhanced PLRS user unit (EPUU) for manpack, vehicular, and aircraft installations. The net control stations (NCSs), located at the division and brigade rear areas, are the upgraded PLRS master stations.

Both PJH and PLRS will assist helicopter aircrews with terrain flight navigation, as described in Subsection 2.2.6. PJH's increased communications capability and the capability for direct aircraft EPUU to other EPUUs without going through the NCS should also assist the aircrew with more effective and timely use of the system for terrain flight navigation.

2.2.8 NAVSTAR Global Positioning System (GPS)

GPS is a multiservice space navigation system with the capacity to provide highly accurate, three-dimensional position, velocity, and time to an infinite number of users anywhere on or near the earth. GPS consists of three segments -- space, control, and user. The space segment will consist of 18 satellites plus three active spares. The constellation is designed so that a minimum of four satellites are always in view, which is the number required for an accurate fix. The DoD-specified accuracy will be within 15 meters. The Army plans to install user equipment in manpack, vehicles, and aircraft. Army Aviation will be a major user, and present plans are to install GPS in aircraft equipped with a doppler or inertial navigation system.

GPS is passive and will provide the aircrew with present position or range and bearing to waypoints, allowing navigation between any two points the aircrew selects. With its three-dimensional capability, GPS can provide course and vertical guidance information for nonprecision

approaches into tactical LZs. When available, GPS can provide redundancy with doppler or inertial navigation systems, thus increasing the probability of mission success.

The primary advantage of GPS versus other systems is its remarkable constant accuracy that greatly assists an aircrew in navigation in terrain flight. Since GPS is passive, this will allow NOE flight in closer proximity to high-threat air defense systems. There is no requirement for manual updating regardless of time flown or distance traveled. This further decreases the aircrew workload. However, GPS will not completely eliminate the requirement for topographic maps.

2.2.9 GPS/Doppler and GPS/Inertial Hybrid Systems

The AN/ASN-128, AN/ASN-137 doppler, and AN/ASN-132 inertial self-contained navigation systems (SCNSs) and NAVSTAR GPS have been described in previous paragraphs and in Appendix B. The aircrew must manually update both doppler and inertial navigators with present-position data to maximize system accuracy. Army aircraft equipped with a SCNS will have GPS user equipment (UE) sets installed, and GPS will continuously update the SCNSs' present position. An integrated GPS/SCNS console-mounted control indicator unit (CIU) will be installed.

Using the AN/ASN-128/GPS hybridization as an example, the CIU will provide for control of the AN/ASN-128 and readout of navigation quantities on the basis of the doppler velocity measurement. The CIU will support several navigation modes: AN/ASN-128-aided GPS navigation, unaided GPS navigation, AN/ASN-128 dead-reckoning without GPS satellite measurement, and memory (position based on last known velocity vector after loss of all GPS and AN/ASN-128 data).

The aircrew assistance with terrain flight listed previously is also applicable to a GPS/SCNS system. Further, the GPS/SCNS hybridization and its inherent significant increase in navigation accuracy should permit the aircrew to use the system for dead-reckoning with almost complete confidence. It would not be inconceivable for the pilot/copilot "pilotage" workload to be considerably reduced, although not completely eliminated. Aircrew workload would also be decreased by eliminating the requirement for SCNS manual position updating.

2.2.10 Night Navigation and Pilotage System (NNAPS)

The NNAPS is a special-purpose, very high-speed digital processing system that uses digitized topographic data stored in an airborne storage device to improve current operational capabilities in autonomous navigation, topographic map generation, and flight and tactical symbology generation. It is currently in the exploratory development phase: and a prototype system is installed at the Avionics Research and Development Activity (AVRADA), which is integrated with the Advanced Helicopter Improvement Program (AHIP).

The NNAPS consists of two major subsystems, a digital map generator (DMG) and an integrated mission planning station (IMPS). The DMG is installed in the aircraft and includes the topographic map display, which can be scaled down in four increments -- from 24x24 km to 3x3 km. The IMPS (which has its own DMG) is required to generate the mission tapes for the airborne DMG. The IMPS will permit aviators and/or operations/ intelligence personnel to plan a mission, enter the information into a storage device such as a cassette, and then transfer that data to the aircraft.

By comparing terrain below the aircraft with stored terrain data, the NNAPS has the potential for extremely high accuracies in position information and does so as an autonomous system. The digital terrain elevation data base is used to automatically update the doppler navigation system, giving it a potential accuracy of 50 meters or less. These same data also form the foundation of the digitally generated moving-map display. This topographic map display (in the aircraft and IMPS) can be used for preflight planning or in-flight evaluation. The topographic map display presentation on a cathode ray tube (CRT) appears as a contour-line map with color-coded terrain elevations. The DMG also provides perfect registration and overlay of flight symbology. The system will feature a unique control display unit that will provide a high degree of flexibility in generating displays for NOE operations.

The Aviation Branch has not identified any definite aircraft applications to date; but possible applications are in the OH-58D and AH-64 aircraft.

The NNAPS will improve aircrew performance in NOE and low-visibility environments and reduce aircrew workload through the elimination of handheld maps. Navigation workload and head-down time in the cockpit will be minimized. In addition, aviators require many different types of information on a single map, yet map clutter must be avoided to the greatest extent possible. With the DMG the aircrew can select the information needed to provide a map optional for the momentary situation, thereby controlling the classes of information that are required to be displayed (e.g., vegetation, highways, hydrography). Since the present position of the aircraft is always displayed, versus the expected position on the programmed course, theoretically the aircrew is never "lost." Another aircrew aid to navigation via the DMG is the impressive feature of any information to be upgraded through data links from the ground or other aircraft. An entire route of flight or a new destination can be passed, and since present aircraft position is displayed, NOE flight to the changed route should be routine.

2.2.11 Other Systems Considered But Not Evaluated

Table 2-2 lists the systems considered for ground guidance navigation but not evaluated. The reasons for elimination from further consideration are as follows:

- The Doppler Radar Velocity Sensor (DRVS) was being developed as a possible doppler navigation system replacement but has been eliminated from further consideration according to personnel at AVRADA.

- OMEGA systems with growth potential for GPS updates were originally included. These systems were eliminated because of the severe inaccuracy of OMEGA, and the programmed GPS will be more accurate individually than in combination with OMEGA.

- Integrated Communication, Navigation, and Identification Avionics (ICNIA) is without a stated navigation system and therefore cannot be considered a candidate by itself.

- The Army Digital Avionics System (ADAS) is strictly a test bed; thus it is excluded since there are no plans for deployment. It will be used only for test, evaluation, and demonstration.

- The various lighting systems (e.g., coherent light, reflectors, tritium light, infrared, pulse light approach slope indicator [PLASI], visual approach slope indicator [VASI], and precision approach path indicator [PAPI]) were eliminated as a result of the exploitability, numbers required, and the manpower required to reorient every four to six hours in the forward area or cross-front line of troops (FLOT).

- Radiometric area correlator (RAC) technology definitely offers promise if the cost can be kept low; however, there is no concerted effort at present to develop this as a navigation system, although the system in the AH-64 is similar. The development of a RAC-type system was recommended in the previous report.

2.3 FACTORS CONSIDERED

The U.S. Army Air Traffic Control Activity (USAATCA) originally provided 23 factors to be considered in evaluating alternative ground guidance systems. After reviewing these factors, we prepared a discussion paper that was used to gain USAATCA's concurrence on a general definition and regrouping of the factors. A copy of this discussion paper is provided in Appendix C. The factors, which were grouped into categories of operations, maintenance, and support, are presented in Table 2-3.

TABLE 2-2

OTHER SYSTEMS EXAMINED

Doppler Radar Velocity Sensor (DRVS)
OMEGA (Tracor 7900, Litton LTN-211)
Integrated Communication, Navigation, and Identification Avionics (ICNIA)
Army Digital Avionics System (ADAS)
Coherent Light
Reflector
Tritium Light
Infrared (IR)
Radiometric Area Correlator (RAC)
Pulse Light Approach Slope Indicator (PLASI)
Visual Approach Slope Indicator (VASI)
Precision Approach Path Indicator (PAPI)

TABLE 2-3

FACTORS CONSIDERED FOR GROUND GUIDANCE EVALUATION

Operations	Maintenance	Support
Interoperability	Maintenance Concept	Supportability
With PLS	RAM	Manpower Needs
With Non-PLS	Ancillary Equipment	Type Power and Availability
With ATM Functions	Special Handling Equipment	Manpower Structure
Susceptibility	Ease of Installation	Commonality
RF Emanations	Useful Life	Life-Cycle Costs
Light Emanations		
Strategic Deployability		
Tactical Employment		
Weather Capability		
Night Vision Systems		
Personnel Hazards		

2.4 SUMMARY

This chapter presented the requirement for a ground guidance system, alternative candidate systems, and factors to be considered in evaluating these systems. Chapter Three describes our methodology and evaluation of the systems.

CHAPTER THREE

FACTOR AND SYSTEM EVALUATIONS

This chapter presents a discussion of the aviator factors survey, including problems at NOE levels, the evaluation methodology, the engineer alternatives survey, the results of our evaluation, and a sensitivity analysis. Appendix D is a listing of all personnel interviewed and locations visited during our evaluation.

3.1 FACTORS SURVEY

After developing the set of factors in conjunction with USAATCA, ARINC Research contacted the U.S. Army Development and Employment Agency (ADEA) at Ft. Lewis, Washington; the XVIIIth Airborne Corps at Ft. Bragg, North Carolina; and the 101st Airborne (Air Assault) Division at Ft. Campbell, Kentucky. Tables 3-1, 3-2, and 3-3 provide a cross-section description of surveyed personnel and their experience in NOE hours and aircraft flown. These aviators were asked to describe problems with and requirements for guidance at very low altitudes in preparation for an eventual evaluation of ground guidance requirements.

One thread that weaved consistently throughout the surveys is that flight minimums in peacetime are generally 300 feet vertical and 1/2 mile horizontal visibility (see Table 3-4). These minimums produce a phenomena not noticeable for pilots who may only practice navigation at NOE altitudes in relatively clear (VMC) conditions; that is, terrain features, both natural and manmade, may not be as readily available to orient with, and from, when adverse weather covers the tops of, or obscures, prominent features. This prompted the question of what is adverse weather? All operational and organizational (O&O) plans for U.S. Army helicopters in the immediate future require the aircraft to operate either in all weather (most severe case) or adverse weather. There is no approved definition for "adverse weather" in the U.S. Army lexicon. ARINC Research held exhaustive discussions at the three previously mentioned locations plus DCS for Combat Development, Ft. Rucker, and USAATCA, Ft. Huachuca. The

TABLE 3-1

EXPERIENCE PROFILE OF PERSONNEL SURVEYED (FT. LEWIS)

Rank	Number of Hours NOE*	Aircraft Flying Now	Aircraft Flying Former	Training Location
0-4	200	UH-1H, OH-58	U-8, T42, T41, 0-1	Unit
	200	OH-58A/C	UH-1H	Unit
CW4	1500	UH-60	OH-58, UH-1	NOE School, Yakima, WA West Germany
	750	OH-58	AH-1G	Unit
	2000	CH-47B	UH-1A/B/D/H, OH-6A/B/C, OH-58C, CH-47C	Unit
	1000	JOH-58C	CH-47, UH-1	Unit

*Range = 200 to 2,000 hours NOE. Average = 940 hours.

consensus definition resulting from these discussions is a function of the aircraft and its mission requirement. For example:

- Attack aircraft: Adverse weather is a function of visibility and the minimum/maximum range of its weapons system -- perhaps 50 feet vertical and 500 feet horizontal.

- Cargo aircraft: Adverse weather is a function of the type and location (external/internal) of the load -- perhaps 50 feet vertical and 100 feet horizontal.

Another major concern for all the pilots was the reliability and maintainability of any ground guidance system finally accepted. Many questioned the ability of today's Army to maintain more sophisticated equipment and stated that there were insufficient maintenance technicians to maintain even today's VHF omnirange receivers (VORs) and automatic

TABLE 3-2

EXPERIENCE PROFILE OF PERSONNEL SURVEYED (FT. BRAGG)

Rank	Number of Hours NOE*	Aircraft Flying: Now	Aircraft Flying: Former	Training Location
0-3	300	OH-58A/C	UH-1H	Unit
0-2	50	UH-1H		Unit
	175	OH-58C		Unit, Ft. Irwin (National Training Center), JAAT
CW3	250*	CH-47B/C/D	UH-1D, H Hughes 500C/D	Units
CW2	100	UH-1H		Unit, El Salvador, Egypt
	100	UH-60		Unit
	700	UH-60	UH-1H	CONUS Units and Overseas

*Range = 50 to 700 hours NOE. Average = 240 hours.

direction finders (ADFs). In addition, the supply problems are difficult even now for today's aircraft and air traffic control (ATC) systems.

After gathering the comments from several U.S. Army tactical aircraft unit locations and the 1st Marine Aircraft Weapons Training Squadron at the Marine Corps Air Station, Yuma, Arizona, an independent list of aviator-desired requirements was priority ranked at the last location visited, Ft. Campbell, Kentucky (see Table 3-5). The factors selected by the aviators did not have a direct correlation with the factors agreed upon originally (Section 2.3 and Appendix C). These new factors were ranked from 1 to 23 (1 = good, 23 = low). The average score for each was then computed. For example, accuracy was rated first (1) by three aviators (1 x 3 = 3) and second (2) by five aviators (2 x 5 = 10); therefore, the total rating points were 13 and total raters (8 raters or aviators) provide

TABLE 3-3

EXPERIENCE PROFILE OF PERSONNEL SURVEYED (FT. CAMPBELL)

Rank	Number of Hours NOE*	Aircraft Flying		Training Location
		Now	Former	
0-4	200	UH-60	OH-58, UH-1	Unit
CW-4	500	CH-47D	OH-6A/C	Unit
	1000	UH-60	UH-1	Unit
CW3	1000	UH-60	UH-1, AH-1, OH-58	
	1000	UH-60	UH-1, AH-1	Unit
CW2	20	UH-60	UH-1	Unit
	40	UH-60	OH-58	Unit
	500	UH-60	UH-1H	Unit
	500	OH-58A/C	UH-1H	Unit

*Range = 20 to 1,000 hours NOE. Average = 530 hours.

an average of 13/8 or 1.63. The factors were then listed by descending average and assigned an ordinal rank. The factor "accuracy" rated one (1). Note that three of the aviator factors had identical averages; therefore, a suffix was added to differentiate, i.e., 13A, 13B, and 13C.

3.2 EVALUATION METHODOLOGY

The original methodology discussed with USAATCA in October 1985 was to have both the factors and the alternative systems rated by U.S. Army aviators. However, because of the Army aviators being unfamiliar with several of the systems, this approach was modified. The aviators selected and ranked the factors presented in Chapter Two, Section 2. Then, civilian engineers, who were also pilots, performed the comparative ratings of

TABLE 3-4

ARMY VFR WEATHER MINIMUMS
(UNCONTROLLED AIRSPACE)

Operation	Ceiling (Feet)	Visibility*	
		Rotary Wing	Fixed Wing
Daylight			
Flat Terrain	300	1/2	1
Mountainous Terrain	500	1/2	1
Night			
Flat Terrain	500	1	2
Mountainous Terrain	1000	1	3

*Conditions as reported or forecast in statute or nautical miles.

Notes:

1. When weather conditions are less than those above, tactical helicopter training may be conducted in approved tactical maneuver/training areas with the following restrictions:

   - When clear of clouds
   - At an airspeed allowing visual contact with other aircraft for avoidance purposes
   - With 1/2-mile visibility
   - With ATC clearance when operating in a control zone
   - With approved vertical helicopter IFR recovery procedures
   - With aircraft equipped for IMC flight and with appropriate avionics

2. Information extracted from Table 4-1, Change 3, AR 95-1, 5 August 1984.

TABLE 3-5

REQUIREMENTS RATINGS

Factor	Average Rating	Ordinal Ranking*
Accuracy	1.63	1
Reliability	1.75	2
Confidence	3.00	3
Maintainability	4.25	4
Low Workload, In-Flight	4.75	5
Low Workload, Pre-Flight	5.29	6
Terrain Information	5.67	7
Night-Vision-Capable	6.00	8
No Ground Site Dependency	6.17	9
Passive Aircraft	6.29	10
Distance Display	6.40	11
Bearing Display	6.50	12
Human Factors	7.00	13A
Integrated with Other Displays and Avionics	7.00	13B
Not Platform-Unique	7.00	13C
Variable Scale	7.33	14
Weather	7.50	15
BITE	8.00	16
Passive Ground	8.50	17
Common Feel	10.00	18
Low Cost	11.50	19
Ground Deploy < 30 Minutes	15.00	20
Easy Training	16.00	21

*Used as a contributing factor number; see Table 3-6.

alternative systems versus the factors. The methodology is illustrated in Figure 3-1. Table 3-5 was the initiation point. There was not a direct correlation of the aviator factors and the original factors.

In some cases the relationship was obvious; in other cases the 10 to 12 hours of dialogue on cassette recordings was used to determine the essential nuance intended by the aviators. On the basis of this exhaustive examination, the aviator factors were merged into the original factors (see Table 3-6). In Table 3-6 the second column has the ordinal ranking as used in Table 3-5. Since not all aviators chose to rank all their factors, the sum of rating points and the number of total raters

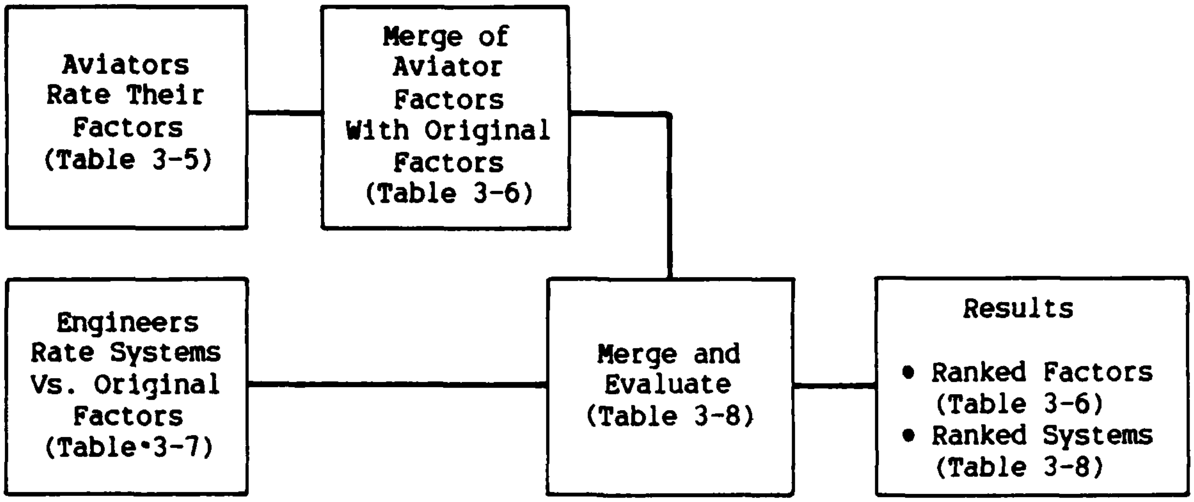


FIGURE 3-1

SURVEY METHODOLOGY

(aviators) were listed. A global average was created for each of the major factors (subelements of interoperability and susceptibility were summed) by dividing rating points by total raters. An example of this merging is "RF (Emanations)" under "Susceptibility." This factor was composed of numbers 10 and 17, which were "passive aircraft" and "passive ground" in Table 3-5. Seven aviators rated passive aircraft with an average score of 6.29; therefore, its score is 44 rating points (7 x 6.29). Likewise, six aviators rated passive ground with an average of 8.50; therefore, its score is 51 rating points. The sum of these is 95, as shown in Table 3-6. The total number of raters is 13. Susceptibility global average was then calculated by adding rating points for both "RF" and "Light" (95 + 101), equaling 196, and dividing by total raters (13 and 14), giving a global average of 7.26. This "global average" became the aviator weighting factor used in Section 3.4.

3.3 ALTERNATIVES SURVEY

Engineers with helicopter experience rated each of the systems versus the original factors (see Table 3-7) on the basis of an analysis of available systems and discussions with avionics engineers. One category that has not been mentioned directly, but was prominent in the engineer discussions and will be used as a discriminator, is "duality of purpose"; that is, systems that are programmed for another purpose, but that will fulfill the second or parallel mission of ground guidance, will bear heavily in the selection of the best approach.

TABLE 3-6

AVIATOR MERGED RATINGS

Original Factor	Ordinal Ranking*	Rating Points	Number of Aviator Raters	Global Average	Overall Ranking
Operations					
Interoperability		244	52	4.69	2
With PLS	1,3,5,11,12,13A,13B,15	149	31		
Non-PLS	11,12,13A	59	9		
ATM	1,3,14	36	12		
Susceptibility		196	27	7.26	14
RF	10,17	95	13		
Light	8,10,17	101	14		
Strategic Deployability**	--	-- --	-- --	--	--
Tactical Employment	5,6,9,10,17,20	222	35	6.34	9
Weather Capability	1,3,6,7,11,12,13A,13B,14,15	185	36	5.14	6
Night Vision	1,3,6,7,8,11,12,13A,13B,14	176	35	5.03	4
Personnel Hazards	4,5,6,13A,13C	137	27	5.07	5
Maintenance					
Maintenance Concept	4,16,13C,19	126	18	7.00	13
RAM	2,3	17	9	1.89	1
Ancillary Equipment	4,13C,16,21	96	15	6.40	10
Special Handling	9	37	6	6.17	8
Ease of Installation	4,13C	48	10	4.8	3
Useful Life**	--	-- --	-- --	--	--
Support					
Supportability	6,13C,21	67	10	6.70	12
Manpower	6,9,21	90	14	6.43	11
Type of Power**	--	-- --	-- --	--	--
Modular	4,20	49	9	5.44	7
Commonality	13C, 18,19	90	9	10.00	15
Life-Cycle Costs	19	46	4	11.50	16

*Used as a contributing factor number; see Table 3-5.

**These factors are not rated. Aviators believe that potential ground guidance systems will be installed on helicopters, thus presenting no strategic deployability problem. Aviators also presumed that aircraft power would be adequate for any ground guidance system. In addition, they believe that although life-cycle costs are important, most systems will be superseded, modified, or replaced before the end of the useful period.

TABLE 3-7

ALTERNATIVES SURVEY

Factor	Average Rating by System								
	Pilotage	NDB	DNS	INS	PLRS	PJH	GPS	NINAPS	GPS Inte-grated
Interoperability	NA	1	NA	NA	4	3	2	NA	2
Susceptibility	NA	7.5	6.5	1	2	2	4	6	4
Strategic Deployability	1	2	1	1	7.5	7.5	1	5.5	1
Tactical Employment	1	7	1	1	6	6	1	5	1
Weather Capability	8.5	7	4.5	4	4.5	4	5	1	2
Night Vision System Use	8.5	1.5	1.5	1.5	1.5	1.5	1.5	4.5	1
Personnel Hazards	1	4.5	3.5	1	1	1	1	1	6
Maintenance Concept*									
RAM**									
Ancillary Equipment	NA	4.5	1.5	1	7	7.5	3.5	6	4
Special Handling Equipment†									
Ease of Installation††									
Useful Life	NA	4	2.5	2.5	4.5	6	1	7.5	1
Supportability	1	1.5	2	6	7	8	2	9	2
Manpower Needs	1	9	1	1	6.5	6.5	1	7.5	1
Type Power and Availability	NA	1	3	3.5	5.5	4	1	6	NA
Modular Structure#									
Commonality	1	4.5	6.5	7	3	3	1	4	8.5
Life-Cycle Costs	1	2	4	5.5	5.5	7	2.5	9	6.5
Total Score	24	57	38.5	36	65.5	67	27.5	72	40
Scored Areas	9	14	13	13	14	14	14	13	13
Average	2.7	4.1	3.0	2.8	4.7	4.8	2.0	5 5	3.1
Ranking	2	6	4	3	7	8	1	9	5

*Not defined for all systems, but engineers believed this would be set to the Army's advantage and could see no rating inequality.

**RAM data are highly controversial, are frequently not releasable, and/or are classified. In some cases, data provided were significantly different, in other cases data were from specifications only. Appendix C provides a table of values for number of maintenance levels, MTBF, MTTR, and estimated number of avionics boxes. Without reliable data, the category was not graded; however, a sensitivity analysis was conducted, allowing all except "pilotage" to be rated 1 to 8. These results are also provided in Appendix C and show relatively little ranking change.

†Special handling equipment was included in ancillary equipment rating.

††Ease of installation was considered part of RAM; therefore, it was not rated.

#Modular structure was considered part of original design and not relevant to rating; therefore, the engineers declined to rank.

3.4 FINAL SURVEY MERGE AND EVALUATION

A compiled matrix (Table 3-8) was required that would provide a numerical value by merging the engineers' survey (Table 3-7) and the aviators' ratings (Table 3-6). For example, Table 3-8 has a value of 4.7 for NDB interoperability, derived as follows: from Table 3-6, interoperability rated 4.69. In Table 3-7, the engineers rated NDB interoperability as 1.0. The value in Table 3-8 was developed by multiplying 4.69 (interoperability rating) by 1 (NDB interoperability rating) = 4.69. The 4.69 was rounded to the tenths column (4.7). The column scores were then summed (Total Score). The applicable global averages were summed only for the rated factors (Scored Areas). The average was determined by dividing the Total Score by Scored Areas; i.e., Pilotage: 132.5 divided by 57.21 = 2.3.

The merge of these two ratings (Table 3-8) is significant in that neither rating group knew the other's results; yet, when the relative rankings of systems are examined (Table 3-7 and 3-8), the ranking remains the same.

3.5 SENSITIVITY ANALYSIS

As noted in Table 3-7, the RAM versus alternative systems evaluation received no ratings because of the lack of or inconsistency of data. However, since reliability and maintainability ranked so high among the aviators, RAM was artificially varied from values of 1 to 8 on the engineers survey, as shown in Figure 3-2. The high and low of this variation are delineated by an X. There is an overlap in average scores of DNS, INS, and GPS integrated. In addition, and to be expected, there is an overlap of PLRS and PJH average scores. The areas not rated by the aviators were also examined, first by deletion, then with a weight of five. There is no significant change.

One item of numerical significance not previously mentioned is the substantial difference between the present B-kit unit cost of INS (approximately $240,000) versus DNS (approximately $30,000 for ASN-128). This will be a discriminator when choosing a system, since the U.S. Army is currently purchasing significant quantities of DNS and very few of the INS. At the estimated costs provided, there would be almost a $1 billion differential in outfitting the U.S. Army aviation fleet.

3.6 SUMMARY

GPS by itself ranks first; however, the GPS capability will not be realized until the 1990s, leaving the system of choice as "pilotage" and the maps. However, the next systems of choice (in order) are INS, DNS, and GPS hybrid. DNS is a more desirable choice, since the sheer cost of outfitting the Army aviation fleet with INS is overwhelming and a significant number of helicopters currently have a DNS. Other systems such as PLRS and PJH do not rate well, simply because they have not been

TABLE 3-8

EVALUATION MATRIX

Factor	Pilotage	NDB	DNS	INS	PLRS	PJH	GPS	NINAPS	GPS Inte-grated	Global Average*
	Weighted Rating by System									
Interoperability	NA	4.7	NA	NA	18.8	14.1	9.4	NA	9.4	4.69
Susceptibility	NA	54.4	47.2	7.3	15.5	15.5	29.0	43.4	29.0	7.26
Strategic Deployability	1	2	1	1	7.5	7.5	1	5.5	1	1**
Tactical Employment	6.3	44.4	6.3	6.3	38.0	38.0	6.3	31.6	6.3	6.34
Weather Capability	43.7	36.0	23.1	20.6	23.1	20.6	25.7	5.1	10.3	5.14
Night Vision System Use	42.8	7.5	7.5	7.5	7.5	7.5	7.5	22.6	5.0	5.03
Personnel Hazards	5.1	22.8	17.7	5.1	5.1	5.1	5.1	5.1	30.4	5.07
Maintenance Concept	Equality Not Rated									
RAM	Not Rated									
Ancillary Equipment	NA	28.8	9.6	6.4	44.8	48.0	22.4	38.4	25.6	6.40
Special Handling Equipment	Combined With Ancillary Equipment									
Ease of Installation	Not Rated									
Useful Life	NA	4	2.5	2.5	4.5	6	1	7.5	1	1**
Supportability	6.7	10.0	13.4	40.2	46.9	53.8	13.4	60.3	13.4	6.70
Manpower Needs	6.4	57.9	6.4	6.4	41.8	41.8	6.4	48.2	6.4	6.43
Type Power and Availability	NA	1	3	3.5	5.5	4	1	6	NA	1**
Modular Structure	Not Rated									
Commonality	10.0	45	65	70	30	30	10	40	85	10.00
Life-Cycle Costs	11.5	23.0	46.0	63.2	63.2	80.5	28.8	103.5	74.8	11.50
Total Score	132.5	341.5	248.7	240.0	352.2	372.4	167.0	417.2	297.6	
Scored Areas	57.21	77.56	72.87	72.87	77.56	77.56	77.56	72.87	76.56	
Average	2.3	4.4	3.4	3.3	4.5	4.8	2.2	5.7	3.9	
Ranking	2	6	4	3	7	8	1	9	5	

*No ranking by aviators; therefore, unity was used.
**See Table 3-6.

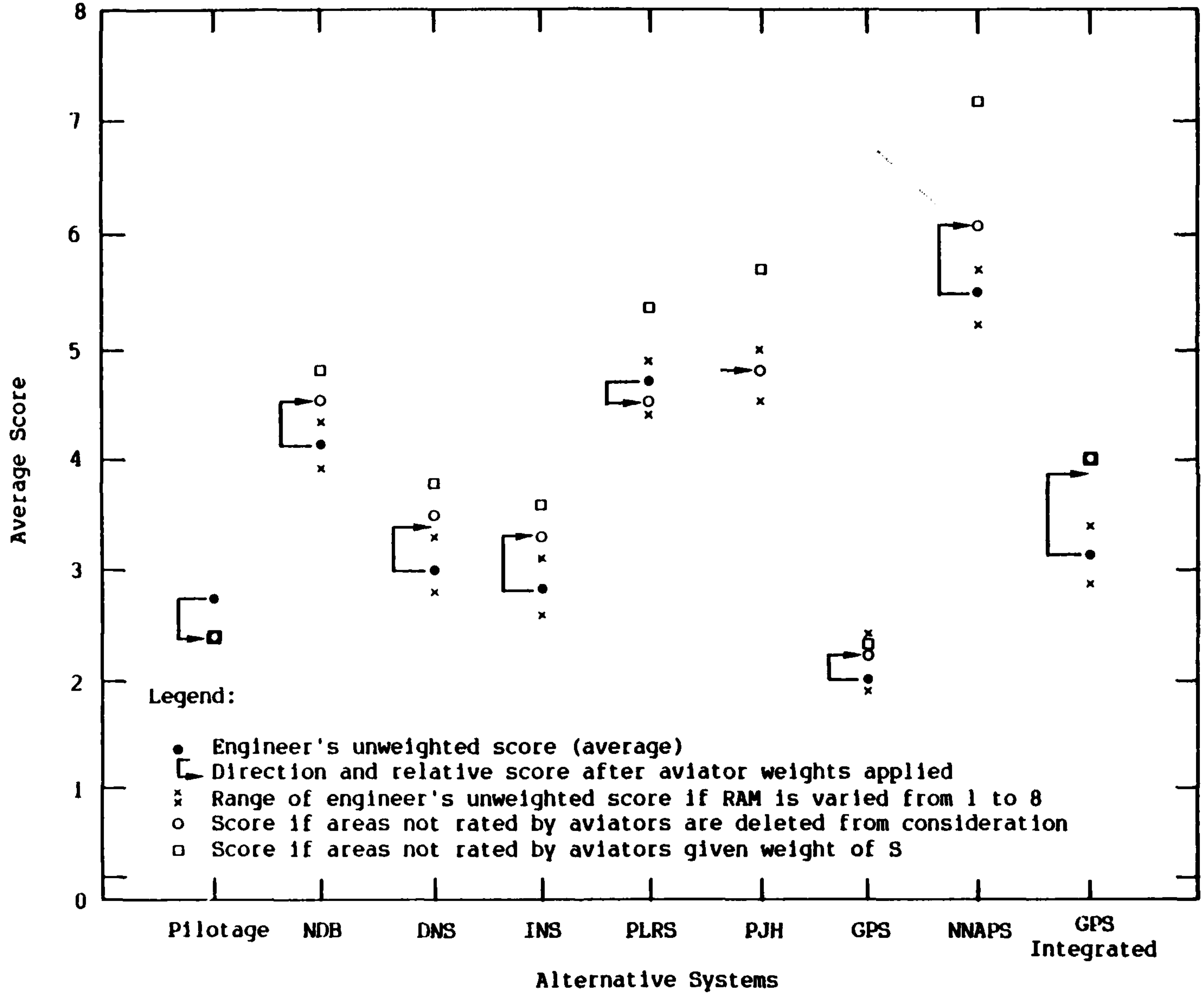


FIGURE 3-2

SENSITIVITY ANALYSIS

thought of as navigation systems. NNAPS has too little present exposure to rate higher; however, a system such as this must be utilized to fulfill future one-pilot helicopters.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

On the basis of the evaluation conducted, ARINC Research presents the following conclusions:

- Systems with a dual capability, including the capacity to provide ground guidance at NOE altitudes in IMC conditions, are preferable instead of a single-purpose system developed strictly for the ground guidance mission.

- The near-term system of choice is the DNS, the AN/ASN-128, or the -137. We have concluded that the DNS is preferable to the AN/ASN-132 INS, because of the relatively high cost of the -132. Similarly, we have concluded that the DNS is preferable to the GPS, because of the great uncertainty in the fielding date of GPS. However, without the ability "to see" in Category III IMC conditions, the inaccuracy of the DNS system, and the possible exploitation of the doppler signal, the pilotage system will still be primary and the aircrew must remain in eye contact with terrain features.

- The mid-term choice is DNS with GPS integrated. The pilotage system will remain primary.

- The far-term choice is the same as the mid-term, but a NNAPS-type system must be provided if there will be single-pilot aircraft, e.g., LHX.

- Currently, there is limited adverse weather NOE capability in today's aircraft, although new night vision and IR systems offer additional capability. No present helicopters can fly IMC at NOE altitudes.

- PJH, although a command and control system, will prove useful but only as a back-up navigation system.

- Inertial navigation systems (INS), although much more accurate and less susceptible than DNS, are far too expensive (approximately $240,000 for INS versus $30,000 for DNS per B-kit) for the several thousand non-SEMA aircraft.

4.2 RECOMMENDATIONS

On the basis of the results of our evaluation, the following actions are recommended:

- The pilotage system should be retained, and pilots should be trained continuously in the two-man system of flying NOE, using the topographic map. Doppler navigation should be used to assist.

- Procedures must be developed and practiced on how to quickly and efficiently transition from the Army Precision Landing System (APLS) sequence to ground guidance, especially for conditions less than VMC.

- The following are the ground guidance systems of choice:

  -- Near term: Continue to provide DNS (AN/ASN-128/137) for aircraft required to operate at NOE altitudes, especially in the forward area and cross-FLOT.

  -- Mid-term: GPS should be provided and should be fully integrated with DNS.

  -- Far term: Same as mid-term plus a NNAPS-type system that, coupled with a heads-up display, is mandatory in envisioned single-pilot aircraft when operating in NOE. Far-term solutions must be carefully monitored to preclude excessive workloads or possible loss of pilot skills in basic navigation with map and compass.

APPENDIX A

AIRLAND BATTLE AND TERRAIN FLIGHT

This appendix presents an overview of the AirLand Battle and a discussion of terrain flight, together with a description of some of the terrain flight problems at NOE levels.

1. ARMY DOCTRINE

AirLand Battle doctrine requires employment of tactical helicopters as an integral part of the combined arms team, who must perform a variety of tasks. Army aviators must be trained to enhance the ground commander's capabilities in one or more of the five functions of land combat: firepower, intelligence and electronic warfare (IEW), maneuver control, air defense, and combat service support. These functions of Army aviation require an impressive array of diverse missions, and the missions required depend on the aviation unit type, the combat arm served, the tactical situation, and the type helicopter.

2. ARMY TERRAIN FLIGHT LEVELS

Terrain flight consists of three levels of flight with varying degrees of difficulty:

- Low-level flight is flight conducted at a selected altitude, approximately 100 feet above ground level (AGL) to avoid detection and observation. Low-level flight is normally conducted on a preselected straight line and is flown at a constant airspeed and indicated altitude.

- Contour flight is flown at approximately 50 feet AGL, conforming with the contours of the earth's surface. Contour flight takes advantage of available natural or other concealment and is characterized by varying airspeed and altitude as vegetation and obstacles permit.

- NOE flight is flown as close to the earth's surface as vegetation and obstacles permit while generally following the contours of the earth's surface. It is characterized by the varying of airspeed

and altitude as influenced by the terrain, weather, ambient light, and the enemy situation. A longitudinal axis is selected pointing toward an objective; but when flying toward the objective, the aircrew uses a weaving and devious route oriented along the axis to take advantage of the cover and concealment afforded by terrain, vegetation, and manmade features. Airspeed may be as slow as zero (hovering), and altitude is usually below prevailing vegetation levels.

3. TERRAIN FLIGHT PROBLEMS

As a result of the projected air defense weapons threat, Army aviation is committed to NOE flight (including cross-FLOT operations); however, it greatly increases the likelihood of geographic disorientation resulting from the aircrew's limited view of checkpoint features useful in navigation.

A helicopter aircrew that has made an instrument approach to a remote landing zone may break out under the ceiling in weather that precludes immediate terrain flight to an objective area. They could then air-taxi to a concealed area guided by a marshaller using hand and arm or light signals. If the ceiling and visibility permit terrain flight, the aircrew could continue to the objective area that could be a tactical objective, FARP, a medical evacuation (MEDEVAC) point, or resupply location. The distance from the point where the instrument approach terminates to the tactical objective may vary from a few hundred meters to more than 10 kilometers. If the objective area is in the vicinity of the maneuver brigades, an NOE path that will avoid known or suspected enemy air defense systems must have been preplanned or must be transmitted to the aircrew via a command and control system.

Unlike low-level or contour flight in which an aircrew can follow a route by identifying a series of preselected checkpoints, NOE flight requires continuous orientation by identifying all terrain features by reference to a topographic map, normally 1:50,000 scale. This is an extremely demanding and dangerous activity for the aircrew, requiring precise teamwork and coordination. It is <u>essential</u> that the pilot at the flight controls concentrate exclusively on controlling the aircraft and clearing obstacles. He must be free at all times to keep his vision directed outside the cockpit, avoiding distractions, particularly cockpit-related ones, which would hinder his external scanning pattern. The pilot announces his visual terrain and landmark information to the copilot to assist in navigation. The copilot must remain oriented at all times using the map, and also using whatever navigation systems or instruments are aboard that particular helicopter. He informs the pilot of the direction and altitude to be flown and appropriate airspeed adjustments for timing purposes. He also assists the pilot by monitoring cockpit instruments and the mechanical functioning of the aircraft. The lower airspeeds of NOE flight allow the pilot the opportunity to see obstacles and hazards and to react by maneuvering to avoid them. Adverse weather, especially reduced

visibility, requires further airspeed reduction and speeds may range from hover to fast air-taxi.

Adverse weather is the most serious hazard to NOE flight, especially in mountainous terrain. When the aircrew's visibility is reduced by flying into the sun or by haze, drizzle, rain, fog or snow, altitude must be increased and/or airspeed reduced to gain additional time to react to avoid obstacles. Obviously, altitude cannot be increased if this change will place the aircraft in an enemy air defense system envelope.

APPENDIX B

ALTERNATIVE SYSTEM DESCRIPTIONS

This appendix provides details of the evaluated alternative systems.

NATO STANAG 2351

The objective of this agreement is to standardize procedures for the United States and the other NATO countries to be used by marshallers/ guides directing ground measurements of helicopters in multinational land operations. Marshallers are trained to use hand and arm or light signals. It is a common procedure for contact between marshallers/guides and helicopter aircrews approaching a landing site to load or unload personnel or material and for guiding each helicopter with minimum delay to its selected landing point. The marshaller must remain in view of the pilot when directing the movement of the aircraft. When handover to another is required, the initial marshaller will not direct his attention away from the aircraft until positive control by the second marshaller is attained. Signals for controlling a hook-up man, an individual responsible for attaching an external load, are also included in the STANAG but are not applicable to ground guidance.

It is normally the responsibility of the supported unit to provide the trained personnel, but these procedures are taught to U.S. Army ground personnel helicopter aircrew members. Therefore, after landing in adverse weather at a site where no trained marshallers/guides are available, the pilots could have one of the enlisted aircrew members disembark and direct them to air-taxi to a landing area and shutdown.

LDNS, AN/ASN-128

The AN/ASN-128 was selected by the Army as its standard doppler navigation system. It is currently installed in the AH-1S (modernized), CH-47D, OH-58C, EH-60, UH-60A, AH-64A, and some UH-1S. A cockpit-installed CDU displays present position in UTM or latitude/longitude coordinates, velocity, steering, and distance-to-go information. Destination location and en-route waypoints can be preset, added, or changed by the aircrew. The system operates from ground level to above 10,000 feet and is completely self-contained, requiring no equipment external to the aircraft. The LDNS transmits microwave energy in four non-coplanar beams toward the earth's surface. The doppler shift along each of the beam's directions is measured and sent to the computer for use in velocity, navigation, and steering computations.

The doppler radar operates in heavy rainfall and over clouds without degradation of accuracy up to 10,000 feet while maneuvering at extreme pitch and roll angles. Navigational accuracy of the DNS is 0.7 percent of distance traveled when the heading error is 0.5 degrees. The factor limiting system performance in this area is the accuracy of the external heading reference. Navigation accuracy over water is only slightly degraded from that over land, excluding water motion effects. Since the dominant factor in the navigation computation is the heading error, the slightly reduced velocity accuracy of the doppler radar over water does not significantly affect system accuracy. Since a doppler navigation system loses accuracy over distance flown, the aircrew must manually update the CDU with a known geographic present position as often as possible. System performance is not affected by rain, and only 20

milliwatts of highly directional RF power is radiated to minimize threat electronic countermeasures (ECM) and air defense radar detection.

NDB, AN/TRN-30(V1)(V2)

This standard Army low- or medium-frequency radio beacon transmits nondirectional signals whereby the aircrew of a properly equipped aircraft can determine their bearing to the beacon. No direct reading distance information is available. The transmitter output power is 28 watts, and it operates in the frequency ranges of 200 to 535.5 kHz and 1605 to 1750.5 kHz in 500 Hz increments. There are 964 channels available, and it has a transmission range of 46 kilometers with a 30-foot antenna. The AN/TRN-30 is highly portable and can be employed in either a pathfinder or tactical/semi-fixed configuration. It can be operated from a battery or external power and deployed with a 15-, 30-, or 60-foot sectional antenna. The system with a 30-foot antenna can be transported and set up by two people, but a crew of six is required to install the 60-foot antenna.

ILDNS, AN/ASN-137

The AN/ASN-137 is a PIP version of the AN/ASN-128 and is currently being installed in the OH-58D Kiowa. The ASN-128 was modified for MIL-STD-1553 data bus compatibility, operates with the newer helicopter true airspeed (TAS) sensor, and utilizes range/bearing from present position to destination for offset targeting for weapons employment. There is no change in the AN/ASN-128 CDU panel, receiver/transmitter antenna (RTA), or the signal data converter (SDC) mounting dimensions. Like the AN/ASN-128, the AN/ASN-137 is a self-contained doppler dead-reckoning navigator, and its error growth is dependent on radial distance traveled. All performance characteristics are essentially the same as for the AN/ASN-128.

IINS, AN/ASN-132

The IINS cockpit-mounted control/display unit operates the system and displays position, velocity, and steering information similar to the doppler control/display units. It is a self-contained, highly accurate, dead-reckoning navigator that interfaces with the MIL-STD-1553 data bus. The accuracy of the AN/ASN-132 is characterized by an error growth dependent on time of flight; however, its performance is far superior to its doppler cousins. The IINS interfaces with aircraft flight instruments to supply the position, velocity, attitude, and heading information. Since an inertial navigator does not depend on radar transmissions, threat electronic devices cannot jam the system or use RF emanations to detect and track the aircraft.

The four major components -- the control/display unit, inertial navigation unit, TACAN, and signal converter unit (SDU) and the navigation processing unit (NPU) -- weigh 144 pounds and have a combined size of 4100 cubic inches. The inertial systems are also expensive and require approximately 9 minutes of alignment time.

Because the IINS has a modular design and because the Operational Flight Program (OFP) is written in a higher-order language (HOL), namely FORTRAN, the IINS can be adapted to most Army aircraft with minor software/hardware modifications. For example, the TACAN receiver/transmitter and the SCU can be replaced by GPS by removing the units and their mount and installing the GPS receiver. The OFP would be modified to accept the GPS data.

PLRS, AN/TSQ-129

PLRS is a joint Army/Marine Corps program and is primarily a command and control system that provides cooperating users with real-time position locations, navigation information, and assistance with fire support coordination and supplemental communicators. PLRS is based on synchronized radio transmissions in a network of users controlled by a ground-located transportable master station (MS). PLRS user units (UUs) capable of transmitting or receiving information will be manpacked, vehicular-mounted, and installed aboard rotary and fixed-wing aircraft. Each MS can handle a combination of up to 400 UUs over an area of 90,000 square kilometers from ground level to an altitude of 50,000 feet. Communications between UUs must be processed through the MS. Both UUs and the MS are capable of secure communication of 19 message types, including free-text messages. PLRS furnishes ground-position location accuracies down to 15 meters or less, and helicopters can be located to within 50 meters.

The MS includes an electronic map display of the TAOR with unit and aircraft real-time position/navigation information. Ground commanders and aviation staff officers use this principal PLRS subsystem to make tactical decisions about force elements under their control. The displayed data and associated tabular data are available to the command and control facility with a data path to the MS.

The PLRS airborne UU includes a cockpit-mounted pilot control and display panel (PCDP), very similar to the ground UUs. The airborne UU allows the helicopter aircrew to locate their exact position and that of friendly units, navigate to any unit or position entered in the PCDP, and navigate in assigned or planned flight corridors. Just as important, PLRS allows the command and control elements at all echelons to locate and control friendly aircraft. The PCDP will continuously display the azimuth and distance to any position selected by the aircrew, and the azimuth can also be slaved to the HSI or BDHI. The PLRS airborne UU is not a primary aircraft navigation system and is LOS limited but is routinely remoted by other UUs. However, there is no question that PLRS is capable of utilization for ground guidance navigation.

The 9th Infantry Division has been identified as the first Army unit to be PLRS-equipped. Some 9th ID helicopters -- the OH-58C, AH-1S, UH-60A and a command and control UH-1H -- have recently had user units installed. An evaluation with a MS was completed, and the UUs were subsequently removed.

A Department of the Army (DA) decision has been made for PJH acquisition. PLRS and PJH are interoperable, and the Marine Corps still plans to equip their divisions and airwings with PLRS. As of the date of this report, PLRS MSs and UUs are still planned for the 9th ID; however, it has been strongly recommended to wait for the first PJH production units to avoid a retrofit program.

PJH, AN Nomenclature TBD

PJH integrates the capabilities of two systems already developed -- PLRS and JTIDS. The features of both, enhanced by hardware and software modifications and expanded data processing, give the PJH two interoperable real-time data communications systems that are reliable, secure, and jam-resistant. In this hybrid system, the PLRS UU was modified by firmware change, a new secure data link, and the addition of a small interface module that works with other tactical battlefield systems. The resulting enhanced PLRS user unit (EPUU), similar to the PLRS UU, is configured for manpack, vehicular, and aircraft applications. The PLRS MS evolved into the PJH Net Control Station (NCS) through the addition of a JTIDS Class 2 terminal and additional data processing capabilities.

With these changes, the PLRS identification, position location, and reporting facilities are supplemented with additional communication capabilities and the resulting JTIDS integration allows enhanced interface with Air Force JTIDS-equipped aircraft flying in support of Army units. In addition, the EPUU modifications provide direct EPUU-to-EPUU data communications without transmission via the NCS.

The DA has made the decision to field PJH instead of PLRS because of the urgent need for data communications systems capable of supporting the Army Command and Control System (ACCS). At this time the Marine Corps intends to equip its divisions and airwings with PLRS, and PLRS is interoperable with PJH.

NAVSTAR GPS

The NAVSTAR GPS, a multiservice effort, is a worldwide, three-dimensional, radio-position determination and navigation system capable of far greater accuracy than any current navigation system. GPS is resistant to jamming and designed for survivability. It will permit anonymous access by an unlimited number of properly equipped passive users anywhere on or near the earth, at any time of day, under any weather conditions. Achievement of worldwide, two-dimensional navigation capacity is planned for 1988 with three-dimensional full operational capacity possible during 1989.

The three major segments of GPS are the Space Segment, an 18 satellite constellation; the Control Segment, composed of ground tracking and control stations; and the User Segment, consisting of the Manpack/Vehicular (M/V) and Aircraft Sets. The satellites will operate in a circular 10,900-nautical-mile orbit within a 12-hour period and will be precisely arranged so that at least four satellites will be in view at all

times. Four satellites are the minimum required to give the receiver an accurate three-dimensional position. The satellites have a lifespan of 7.5 years and will be replaced when they fail to maintain system accuracy.

The basic GPS UE Set consists of an antenna, a receiver/processor unit (RPU) with an interface unit if required, and a control/display unit. Both the M/V Set and the Aircraft Set provide position, velocity, and time (PVT), and navigation data outputs, which are displayed on the control/display unit. The Aircraft Set, when coupled into instruments, can provide three-dimensional steering data, including course and vertical guidance information for nonprecision approaches to instrumented or temporary landing areas. GPS also has the capability for successive waypoint navigation. Army GPS UE Sets are being designed for installation in fixed and rotary wing aircraft, ground vehicles, watercraft, and ground facilities.

The present approach to GPS aircraft integration is to install the system in only those aircraft with an SCNS, either inertial or doppler. The Aircraft Set will function essentially as a navigation sensor that automatically derives rate-aiding for satellite acquisition and tracking from the self-contained system. The RPU receives RF signals from GPS satellites and processes them to provide PVT data that are transferred to the control/display unit and aircraft navigation systems.

The following paragraphs describe the GPS hybridization with the doppler and inertial navigation systems.

<u>GPS/Doppler and GPS/Inertial Hybrid Systems</u>

The dead-reckoning class of navigators, doppler and inertial, are completely autonomous; however, their inherent accuracy is generally incompatible with that required for precise NOE navigation. Interviews with Army aviators have confirmed this statement. An aircrew must know their position exactly, not just during en-route NOE navigation, but also to position weapon systems accurately. To satisfy an increased accuracy for the tactical navigation requirement, the autonomous systems should be bounded by automatic position updates from some externally referenced source. Consequently, the Aviation Branch plans to install GPS UE in aircraft equipped with a doppler or inertial SCNS. Hybridization of two navigation systems will result in a system that can be fully integrated with controls, displays, and appropriate mission equipment on the aircraft.

The complementary features of GPS and an SCNS can be exploited in an integrated system to create synergistic improvements in navigation performance, and a console-mounted-combined GPS/SCNS control indicator unit would be utilized. The GPS will be used to position-update the SCNS, a manual requirement for both doppler and inertial systems, reducing pilot workload and increasing system accuracy. Using the AN/ASN-128 doppler/GPS integrated system as an example, this system will have six basic modes of operation. If GPS and AN/ASN-128 doppler data are available, the velocity-coupled navigation mode will be used and will provide the most accurate navigation possible. If the doppler is unavailable, the true airspeed

(TAS) and heading will be used as a low-accuracy replacement. If the doppler and TAS are unavailable, then an unaided GPS navigation mode will be implemented. If GPS is unavailable, then a dead-reckoning mode using doppler (primary) or TAS and heading (secondary) would be used for dead-reckoning.

The SCNS will reduce the GPS jamming vulnerability and aid the system during LOS satellite blockage. If the aircraft loses the GPS signal because of jamming or a severe maneuver, the SCNS will continue to maintain navigation information and also assist the GPS receiver in reacquiring the satellite signals. Helicopters equipped with a GPS/doppler system that are assigned missions requiring absolutely passive navigation equipment for clandestine operations, cross-FLOT, or in close proximity to known threat surveillance or acquisition radar could shut down the radar-generating doppler.

The Army has tested two UH-60A aircraft equipped with integrated GPS/AN/ASN-128 doppler systems. These tests determined the proper integrated system functions and interoperability with other avionics equipment. Operational performance was also checked during flight tests. The test results exceeded many of the program goals.

However, it is worth emphasizing that GPS navigation may not completely eliminate inertial platforms or present doppler-type navigators. Inertial platforms will still be required in some aircraft for attitude reference and flight control. Further, the signals from GPS are not very strong and could possibly be jammed by threat transmitters. It is also fairly well accepted that even satellites are not immune to direct attack. But until a passive autonomous SCNS is developed that will maintain accuracy and meet space and weight constraints, this hybrid of self-contained and GPS techniques will be required to automatically update the SCNSs and to provide a worldwide position/navigation and approach capability.

Night Navigation and Pilotage System (NNAPS)

The Night Navigation and Pilotage System, an AVRADA program, is in the exploratory development phase. The NNAPS is a special-purpose, very high-speed, digital processing system consisting of flight and tactical symbology generation, topographic map display generation, and an autonomous terrain-aided navigation system. A wide variety of operator-selectable symbology formats are used to display pilotage information that can be superimposed on a FLIR or TV image and navigational information that is superimposed on a map image. It will also automatically update the AN/ASN-137 doppler navigation.

NNAPS consists of two principal subsystems: a digital map generator (DMG) installed in the aircraft, which includes a topographic map display; and a ground-based Integrated Mission Planning Station (IMPS), which is primarily used to generate the mission tapes required for the DMG. The NNAPS has been identified as a system that has promising military applications in future advanced helicopter and high-performance fixed-wing

aircraft. The system will provide Army helicopters with increased operational capability at NOE and low-visibility environments via the digitally generated moving topographic map and will reduce aircrew workloads by almost completely eliminating navigation via hand-held topograhic maps. The system permits computation of a "safe" flight pattern based on terrain and enemy fields of fire and provides many mapping features, including elevation shades of grey; sun-angle slope shading; cultural features such as roads and railroads; full-color capability; overlay of target location symbology; current aircraft position; and display of preplanned route.

The DMG promises major improvements in battle information management and map display and could evolve into an accurate SCNS. By comparing terrain below the aircraft with stored terrain data, it promises extremely high accuracies in position information. It does so as a self-contained system, requiring no manual updates or dependence on external radio signals.

The DMG incorporates techniques to display digitized terrain data on the cockpit-mounted control display system (CDS). It is possible to cover a large operating area and have available mission planning, terrain elevation, cultural and intelligence data, and a recorder track on a single four-track tape. These tracks will contain Defense Mapping Agency (DMA) data, terrain elevation and cultural data on the first and second tracks, respectively. The third track will contain battlefield information data such as troop concentrations, air defense sites, and convoy locations. The fourth track can be annotated in flight by the aircrew with other pertinent data, which can then be applied to other missions or stored in the data base.

Continuously moving-map display modes may be tailored for specific applications, e.g., North-up, track-up, heading-up. The aircraft may be centered or positioned off center. In addition, by software manipulation the map may be rotated from the topographic view 90 degrees to a perspective view so that the aircrew can view the horizon as it actually looks from the cockpit. Four display scales are available: 3x3, 6x6, 12x12, and 24x24 kilometers. The system permits computation of a "safe" flight pattern based on terrain and threat envelopes. It also has a full-color capability, elevation shading, or sun-angle slope shading.

Since NOE navigation in adverse weather is a demanding and complex task, the Integrated Mission Planning Station addresses the planning function. The DMG, by itself, will not satisfy this requirement. The ground-based transportable IMPS closes the loop in the total NNAPS concept by providing the method for generating the DMG mission tapes. The heart of the IMPS is a DMG, an exact duplicate of the display the aircrew will use in the cockpit. The primary function of the IMPS is the preparation of mission-specific cassette tapes, principally with DMA and intelligence data. Complementary functions include mission planning assistance to the aircrew and verification of mission planning via simulated flights before the actual mission must be flown. (The aircraft-installed DMG can also be used for simulated flights.)

Aviation and ground unit intelligence specialists and, most likely, the aircrews assigned to fly the mission, will augment the DMA-produced planimetric data. Included would be overlays of known obstacles to flight, threat air defense envelopes, strength and disposition of friendly and enemy forces, primary and alternative flight routes, targets, air control points, LZ, and FARPS. If required, the mission planners can edit/update old or incorrect data.

The selection of exactly what features appear on the display at any one time is a unique DMG capability. Since the system has the capacity to store large quantities of information, the display would be quite cluttered if all were displayed simultaneously. Buttons along the display allow the aircrew to select or deselect any combination of five tactical categories -- topographic features, target data, enemy situation, friendly situation, and flight paths.

APPENDIX C

GROUND GUIDANCE CHARACTERISTICS

There are a series of factors that, when defined generally, provide a reference to ground guidance requirements. The 19 factors are divided into three subgroups; operations, maintenance, and support.

A. Operations Factors

1. Interoperability

Interoperability is the ability to fit or operate within or between systems and has three subfactors of interest:

a. With Precision Landing Systems (PLS): The chosen system must operate on a low to noninterference basis, enhance, and, if required, integrate at no (low) cost with PLS.

b. With Non-PLS: The system must be interoperable with aircraft navigation systems and related instruments, e.g., automatic direction finder (ADF), horizontal situation indicator (HSI), bearing distance heading indicator (BDHI), tactical air navigation (TACAN), doppler navigation (AN/ASN-128 or -137), and possible inertial navigation systems (INS).

c. With Air Traffic Management (ATM) functions: This system must be compatible and require no unique buffering system to integrate with present and future ATM systems.

2. Susceptibility

Preferably, the system should be passive to reduce exploitation possibilities. Susceptibility has two subfactors of interest:

a. RF emanations: External emanations of RF energy should be low. Any emitter should have a selectable power-output level to afford operation in high-threat situations. Low probability of intercept (LPI) characteristics such as frequency agility or burst transmission are preferred over continuous wave (CW) or other easily detected types of modulation. Ground systems should

operate in a demand mode (activated by user aircraft), if possible, to limit transmitter duty cycle and therefore exploitability.

b. Light emanations: Candle-power output (lumens) or reflective signature(s) should have minimum exploitability.

3. Strategic Deployability

The system, if internal to the aircraft, must present no additional difficulty in strategic deployability for the parent aircraft; i.e., if ground guidance is a separate ground-mounted system, it must be a standard-size configuration and small enough to be deployable in all strategic lift aircraft or ships.

4. Tactical Employment

Ideally, the system chosen should be an internal part of each aircraft and provide no degradation of its tactical employability; in fact, as a result of its purpose, this system should enhance the employment. If the system is externally ground-mounted, it must be capable of being carried by a utility helicopter and no module should require more than a two-man lift.

5. Weather Capability

The system must be capable of operating in the same weather environment as the supported forces, not degrade the unaided eye and enable aircraft to operate beyond the unaided human eye. Use of a ground guidance system in adverse weather must enhance employment of aircraft on the various missions e.g., attack, scout, cargo, observation.

6. Night Vision System Use

The system should operate on a noninterference basis without additional special-purpose equipment and must be color- and intensity-compatible with night vision systems.

7. Personnel Hazards

The system must present no hazard such as electrical, mechanical, or radiation in operation; in maintenance, the system should have no more hazards than other normal avionics systems.

B. Maintenance Factors

8. Maintenance Concept

There should be three levels of maintenance, as follows:

a. Operator/unit maintenance: The system must be sufficiently user-friendly to be capable of training people to fault-isolate with BITE and replace with a line replaceable unit (LRU).

b. Direct support (or Aviation Intermediate Maintenance [AVIM)]: If required, maintenance of the ground guidance should require no more than an add-on skill identifier for present AVIM Military Occupational Specialties (MOS).

c. Depot-Level Maintenance: The system should require either interim contractor support (ICS) or U.S. Army organic depot level. Transition from ICS to U.S. Army depot-level maintenance should occur after a specified period of time.

9. Reliability, Availability, and Maintainability (RAM)

a. Reliability: The system should have a mean time between failures (MTBF) of 1,000 hours or more. If the ground guidance system is on the aircraft, system failures must not cause a safety-to-flight situation.

b. Availability: The system should have an inherent availability of 0.999.

c. Maintainability: The mean time to repair (MTTR) should be 30 minutes or less for the chosen system. No external test equipment is desired below the AVIM level, and unit levels should use BITE. The system must have a self-check diagnostic and failure indication.

10. Ancillary Equipment

Required power supplies should be internal to the system, preferably quiet passive types versus generator types. Auxiliary power is optional.

11. Special Handling Equipment

No unique material handling equipment (MHE) are required for storage, operation or maintenance.

12. Ease of Installation

Form, fit, function (F^3), if ground guidance is a replacement item, it must be of standard size, with desired self-balancing and orientation and minimal alignment requirements.

13. Useful Life

Twenty years is desired.

C. Support Factors

14. Supportability

If internal or external to aircraft, the ground guidance system modules and associated logistics should be low cost and technically low risk; the system should operate with current or planned avionics.

15. Manpower Needs

Installed systems on each using aircraft should require no additional personnel. When ground guidance is a ground-mounted system, it should be expendable and unattended after setup. Fault detections for ground-based systems should be sent to a central unit directly or through an airborne relay within line of site (LOS). Training/training support requirements should be comparable with present ATM equipment. New equipment training (NET) may require additional effort for retraining instructor and maintenance/operator personnel.

16. Type Power and Availability

If ground guidance is a ground system, it must be capable of generating its own power. An aircraft-mounted system should be integrated with an emergency auxiliary bus or back-up power available independently of a primary bus. Availability of power must be greater than or equal to other avionics systems.

17. Modular Structure

No module for a ground guidance system should require a nonstandard-size container; all modules should use Military Standard quick-release/attach devices. There should be a minimal number of structures (modules), no more than one desired if a ground-mounted system. Setup of a ground-based system should require less than 30 minutes under Nuclear, Biological, and Chemical (NBC) conditions requiring mission-oriented protective posture (MOPP) IV gear and/or cold weather gear.

18. Commonality

The system should have no unique items.

19. Life-Cycle Costs

Costs must be minimized. If possible, systems should be multipurpose with ground guidance requirements being met with a system having another purpose.

APPENDIX D

ORGANIZATIONS VISITED AND PERSONNEL INTERVIEWED

Table D-1 lists the military and civilian organizations visited and personnel interviewed during the evaluation.

TABLE D-1

ORGANIZATIONS VISITED AND PERSONNEL INTERVIEWED

Point of Contact	Unit	Date	Discussion Topics
MAJ Dave Deykes	PLRS/PJS Test Officer, CECOM, Ft. Monmouth, NJ	23 Oct. 1985*	Aviation research plans for PLRS and PJH.
CPT Wayne Chappell	Ft. Rucker, Alabama, USAAVNC	11 Sep. 1985	Ft. Rucker's helo student instrument flight syllabus, marginal VFR conditions, and Special Visual Flight Regulations (SVFR).
Mr. Robert Singer	Asst. Mgr., Battlefield Systems Program, Hughes Aircraft	24 Sep. 1985	Forwarded PJH "A" Specifications via John Lioy at CECOM.
CPT Wayne Chappell	Ft. Rucker Alabama, USAAVNC	17 Oct. 1985	Threat air defense in brigade area and requirement for helos to remain at terrain flight altitudes.
MAJ Rich Partleymuller	Opns O, EFTA, Lakehurst NAS, NJ	24 Oct. 1985*	NOE requirements, instrument qualifications, including flight simulators, performing A/C mission in adverse weather, "Battle Captain" doctrine.
Mr. Harry Bahr	Deputy, PLRS/PJH Prog. Mgr, CECOM	28 Oct. 1985	PJH implementation/use in AVN Branch helicopters; brigade airspace coordination problems; lack of specific decisions for type A/C for PJH installations.
Dr. John Niemela	Acting Dir. NAV Div., AVRADA, Ft. Monmouth, NJ	7 Nov. 1985*	Advantages and disadvantages of AN/ASN-128/-137/-132, PJH and PLRS, GPS NVGs, hybrid navigation systems, GPS integration with doppler, and inertial navigation systems (-128/-137 and -132), and the NNAPS' DMG and IMPS. Discussions focused on use of NNAPS for aircrew assistance with terrain flight.

*Locations visited.
**Names deleted because of confidentiality of surveys.

(continued)

TABLE D-1 (continued)

Point of Contact	Unit	Date	Discussion Topics
Mr. Jack Morissey Mr. Ed Moretta Mr. Tom Casagrande	Dept. Army Civ. (DAC) helo test pilots, EFTA, LABCOM, Lakehurst NAS, NJ	8 Nov. 1985*	Same discussions as with John Niemela, but primarily focused on tactical aviators' point of view; discussed heads-up display requirements in SCAT helos.
Mr. Bob Campagna	Proj. Engr. (DMG), AVRADA Research and Technology Div.	9 Dec. 1985	DMG, status of system, and OH-58D DMG installation in AVRADA OH-58D simulator.
Mr. Ken Bly	DAC Helo Pilot, NVG Lab., Davison AAF, Ft. Belvoir, VA	19 Dec. 1985*	NVG and helo applications and tests.
**	38th Annual Helicopter Association International Meeting and Industry Exposition, Anaheim, CA	26-28 Jan. 1986*	Data collection and interviewed industry representatives directly related to ground guidance systems being considered.
**	ADEA and 9th Div., Ft. Lewis, WA	29-30 Jan. 1986*	Initial survey of helo pilots concerning NOE/terrain flight navigation.
Dr. Norm Shupe	Director, Research and Tech. Div., AVRADA Ft. Monmouth, NJ	9 Jan. 1986*	Moving-map displays; primarily focused on NAAPS's DMG and IMPS.
Mr. George Soganeri	Avionics Tech., Doss Aviation (avionics support for EFTA), Lakehurst NAS, NJ	10 Jan. 1986*	Inspected AVRADA's ADAS installation in UH-60 System Testbed for Avionics Research (STAR) aircraft.

*Locations visited.
**Names deleted because of confidentiality of surveys.

(continued)

TABLE D-1 (continued)

Point of Contact	Unit	Date	Discussion Topics
Mr. Bill Schroth	Tracor Aerospace, Marketing Mgr., Avionics Products	10 Feb. 1986	Tracor TA 7900 OMEGA installation in Ft. Campbell and Ft. Bragg aircraft.
**	HQ, XVIII Airborne Corps, Ft. Bragg, NC	26-27 Feb. 1986*	Interviewed helo pilots concerning NOE/terrain flight navigation.
Mr. Kent Brascle Mr. Paul Beckwith	Harris Corp., Govt. Systems Sector, Melbourne, FL	24 Feb. 1986*	Demonstration of NAAPS's DMG; flew DMG flight simulator.
Mr. Dave Kromer	ARINC Research, San Diego, CA	21 Apr. 1986	ASN-128/GPS interface data.
Mr. Mike Larocca	Avionics Tech., Doss Aviation, EFTA, Lakehurst NAS, NJ	2 May 1986*	PLRS, ASN-128, and GPS installations; inspected various aircraft with -128/GPS and UH-60, with AN/ASN-132 installed.
**	101st Airborne (Air Assault) Div., Ft. Campbell, KY	5-7 May 1986*	Interview and final survey.
MAJ Dave Deykes	PLRS/PJH Test Officer, CECOM, Ft. Monmouth, NJ	12 May 1986	PJH/GPS and PLRS/GPS interface.
Mr. Rush Wicker	Standardization Officer, Ft. Rucker (ATZQ-CDC-C)	21 May 1986	Request to forward additional documentation for NATO STANAG 2351.
Mr. John Lioy	Chief, PJH Div., CECOM, Ft. Monmouth, NJ	12 May 1986	PJH formal documents forwarded: PJH Technical Description and GPS interface.
MAJ Mike Potter, USMC MAJ Gary Price, USMC MAJ Paul Blemberg, USMC	Marine Air Wpns Training, Sqdn 1 (MAWTS-1), MCAS Yuma, AZ	25 Mar. 1986*	Interviewed Marine helo instructors to obtain opinions about Army NOE applicable navigation systems.

*Locations visited.
**Names deleted because of confidentiality of surveys.

END

12-86

DTIC